E/CONF.39/D/63
8 Oct. 1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: D.14.

Finland

FACTORY PRODUCTION OF WOODEN BUILDINGS AND STRUCTURE

By Paavo PÖYRY, M.Sc.,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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Factory Production Of Wooden Buildings And Structures.

1588 D.14

by
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1. General

(a) Advantages of prefabricated building

The housing problem is very urgent in many countries, not least in the less developed ones. Investments in building have, however, nearly always an inflatory effect, and therefore governments find it difficult to solve the problem, if they are at the same time trying to stabilize and develop their country's overall economy. Prefabrication is, in many cases, one of the ways to get a practical and feasible solution to the grave housing problem.

The prefabricated building has several advantages over the conventional:

(i) - the price of the buildings is lower. Even in countries where labour is cheap, machines still do the same work cheaper,

(ii) - the need of skilled labour is less on the building site,

(iii) - cheap and waste materials can be used to a greater extent,

(iv) - the standardization of the building components is easier,

(v) - the quality of the buildings is higher,

(vi) - the erection time is short; this is specially important in certain climatic conditions.

(b) Different forms of prefabricated buildings

There are many different degrees of prefabrication, and it depends on the local conditions which one is used.

(i) - The whole building is prefabricated

This is the most complete form of prefabrication, and also often gives the best results. The different parts of the building, that are prepared in the factory following a common plan, will surely fit together, and there is no danger of shortage of some important rawmaterial at the building site. The erection time is very short and the need of skilled labour during it is insignificant.

(ii) - Only certain parts of the building are prefabricated

Depending on local conditions (supply of raw materials, means of transportation, etc.) it may be more advantageous to prefabricate only certain parts of the building. Thus for instance only doors, windows, stairs etc. may be prefabricated in a factory and the heavier elements such as walls, beams and roofs are prepared at the building site from local raw materials.

(iii) - Technical prefabricated methods

Even if the whole building is prefabricated, two different systems can be used:

a. - The pre-cut system

In the wood-building industry, pre-cutting means that the timber components required for the construction of a building, such as joists, wall plates, studs, rafters (and, in some cases, even boards) are supplied machined and cut to length. No assembly, except that of doors and windows is done at the house factory.

In its simplest form, pre-cutting means only the cutting of timber to definite lengths. Prefabrication, however, makes use of the pre-cutting in a more developed form, which, apart from cutting to length, includes the shaping of structural components at the factory by various processes, machining, cutting, boring, pressing, gluing, and so on.

b. - The panel building system

In the panel building system, the external walls, and often partitions also, are made of panels (for instance 4'wide) the height of the wall, with windows and doors ready-fitted into the panels.

Depending on the builders' wishes and local conditions, the flooring and roofing can also be supplied in panels.
Which one of these two systems is more advantageous to use, depends on local conditions. It cannot be said that pre-cut construction is better than the panel system, or vice versa. When deciding on the type of construction to be used, it is necessary to take into account the purpose for which the building will be used, the situation of the site, transport facilities, the skill and wages of the workers and the equipment available.
The advantages of pre-cut construction are:
- small shipping space,
- easy transport, as the parcels can be made fairly small so that they are less fragile,
- the price is somewhat lower than that of a similar building in the panel construction,
- jointless walls,
- conventional appearance is easily achieved,
- conventional methods can be applied in the erection.

The components of a pre-cut building are packed in bundles or crates. In shipment they take less space than the parts of a panel house of the same size, which can be an asset where great distances and difficult transport conditions are involved.
The advantages of panel construction are:
- less work on the site, as the larger part of the work is done at the factory,
- less skilled labour is required in the erection,
- factories can exploit their abundant supplies of short timber in construction,
- fewer pieces to be handled on site.

There are many reasons why the productivity of one man-hour in a factory is greater than the same on the site. The use of permanent machinery, better working conditions etc. are all to the advantage of the factory worker. A panel building makes more use of these advantages, leaving less work to be done on the site.
The pre-cut construction is recommended when transport involves

great distances by sea, or poor communications between factory and site, and where cheap labour is available. A panel construction is recommended where labour is expensive and skilled labour difficult to obtain; and in cases where very rapid erection is required.

2. Different buildings and constructions

(a) Dwellings

This group of buildings is the most important and often forms a very serious social problem. The standard of the dwellings indicates also rather directly the standard of living of a country. Unfortunately, investments in this group have the most direct inflatory effect on the economy.

The prefabricated construction of dwellings can naturally never solve the whole problem, but experience has shown, that, in many cases, very difficult housing problems have found their solution through some kind of prefabrication. The author of this paper has gathered his experience only in the Latin-American countries, but there is reason to believe that conditions in the less developed countries in other parts of the world are similar.

The shortage of dwellings is always greatest in big cities and densely populated areas. The first step to solve the housing problem may be to build temporary dwellings. Buildings of this kind can be made either of loose timber or of prefabricated elements. Time studies have shown that in the erection of properly planned prefabricated temporary buildings so much time is saved that the elements will pay for themselves relatively quickly. In order to serve their purpose fully, these elements must be so designed that they form a complete and flexible whole.

Temporary buildings can be dismantled and re-erected several times. They can be used on one site until a permanent solution has been found to the housing problem, and after that they can be moved to some other area. Of course, there is always the danger that these temporary buildings become permanent, and the original housing problem is forgotten. Therefore, temporary buildings must be used only in most urgent cases and after careful planning.

Which material, form of building and prefabrication is used in the

construction of the permanent dwellings naturally depends greatly on the local conditions. To obtain the best results it is necessary to consider:

- modern design,
- shaping of the material by machinery,
- utilization of raw materials,
- special methods of erection.

Where timber is the traditional material for building, it still remains the basic material also in modern constructions. It can be successfully used with other materials in composite structures. Thus, in the frame of the house, timber is combined with plywood, fibre board, gypsum board, asbestos cement shingles, and so on, to form a strong and attractive structure. It can also be combibed with bricks and concrete so that the conventional local building material is dominant. When planning lowcost housing, prefabricated timber can be used successfully even in such areas, where it has to be transported considerable distances. This is especially true in those cases, where only doors and windows are prefabricated. Standardization of moulding profiles, door and window sizes, etc. becomes then much easier and falls to the benefit of the dwellers.

(b) Public and other bigger buildings

(1) Schools

In the modern world, where science and technology develop rapidly, the importance of school buildings has increased, and they have come more and more into the public eye. As the task of the school is so all-important, it is natural that serious attention should be paid to the school buildings.

In the planning of modern cities, attempts are being made to avoid barrack-like congestion and to create a community with its own public buildings, including schools, beyond the limits of an urban area and surrounded by open country. Architecture has freed itself from the traditional and grandiose styles, and today it is possible to reach a more agreeable solution by starting from the essential requirements at the centre of the problem itself. This new way of thinking is also very valuable when the shortage of schools is big, and the need for new schools has to be satisfied quickly and at low cost.

(iii) Industrial buildings, bridges etc.

In industrial buildings, bridges and similar constructions, unusually long selfsupporting spans are often required. The most usual raw materials used are steel and concrete. However, where timber is available, roof-trusses made of wood have many advantages compared with steel and concrete. They are light, easy to assemble and strong.

In many countries, the prefabrication of wooden roof-trusses and bridges has already been practised for many years and the results have been good. The biggest advantages of the prefabrication are the same as in the construction of houses.

3. Factors affecting the application of prefabricated systems

There are several local conditions affecting the feasibility of prefabrication. The most important are:

(a) Transport facilities

Transportation of prefabricated buildings and constructions generally will prove more advantageous than the transportation of raw materials because no waste material is transported. This is especially important where difficult transport conditions are involved.

(b) Availability of skilled labour

Shortage of skilled labour is a strong factor on favour of prefabrication.

(c) Local rawmaterials

Where no local rawmaterials are available, complete prefabricated buildings and constructions may be the only economical solution. Even if the heavier parts of the buildings can be constructed of local materials, a partial prefabrication often proves advantageous.

4. International cooperation in adapting prefabrication

In the above, the main aspects of prefabrication have been dealt with briefly. There is no possibility to go into great detail as the local conditions vary greatly in different areas, and the methods used have to be modified accordingly. Some questions have not been touched at all, as for instance preservation, which is of vital importance in many areas, but is in itself a separate technical matter.

In the author's opinion, prefabrication is often the right solution

The building of schools is not such an inflattory factor as the building of dwellings. It can be considered more as a profitable investment on long term basis. The communities and the government therefore do not usually hesitate to invest large sums in school buildings. In this connection, the advantages of prefabricated buildings are still more obvious than in dwellings. Especially, where a whole new school system has to be established, as is often the case in less developed areas, prefabrication can be extra ordinarily effective and economical.

In the following there will shortly be dealt with a system developed in Finland for wooden school buildings. It seems reasonable to believe that some similar system can be adapted in most areas.

Series manufacture is the basis of prefabricated house production. School buildings are based on the use of standardized building elements in which the requirements of different types of rooms have been taken into account. In this system, four ceiling heights can be flexibly used together. Wall elements, givinga ceiling height of 11'2", are suitable for classrooms. For staff rooms and other similar rooms 8' has been considered a suitable height, and in corridors 7'6". In theassembly hall and gymnasium the classroom elements can be extended by the use of the lower sections of brick, giving a total ceiling height of 16'. The use of those wallelements with four different ceiling heights is based on a 4' module, which is strictly followed.

Taking into consideration the local conditions and requirements in designing and manufacturing external walls, floors, ceilings, roofs, windows, doors and other house parts, this basic system can be modified to fit nearly everywhere.

(11) Other public buildings

In building hospitals, army barracks and canteens, and so on, the same points of view as applied to schools are important. These buildings are, like schools, usually financed by the governments and communities, which can and must direct the planning and building. It is always worth while to study the possibilities of prefabrication to reach the best economic solution in these heady investments. to the building problems. However, it must be kept in mind, that adapting prefabrication in any form is not simple, and very seldom easy.

The whole idea of prefabrication loses its value, if the work is not planned thoroughly and well. Even in the more developed countries,

much work and experience, accumulated over a long period of time, are needed when new types of prefabricated buildings and constructions are planned, and naturally this is much truer when prefabrication is being started. Haphazard efforts will certainly prove expensive and very easily get the whole method a bad name.

The easiest, quickest and safest way of adapting prefabrication is naturally the importation of prefabricated houses and constructions. Many countries have already practised prefabrication for many years and have also a long experience in exporting to and building in the less developed areas, where conditions are quite different from those in the home country.

A lack or shortage of domestic building materials makes importation the only solution in some cases. The importation of any kind of building components is however often impossible for economical reasons. Also the domestic building industry may strongly oppose the importation. Therefore the only solution is often to establish a domestic prefabricated industry. This, too, has its difficulties, where cooperation between the governments and the United Nations specialized agencies may be necessary.

The problem is naturally in the first hand economic. It may be difficult to interest private enterprises in it without some kind of guarantee. Therefore the governments may have to take the initiative.

The establishment of prefabricated factories may then be realized as follows:

(a) - Some bigger sanitation plan in or near some big city which needs immediate realization, is chosen. Quite a large number of dwellings may be involved. The government may have to finance this first project, but this is only natural, as the question usually has great social importance.

(b) - Connection is sought with some wellknown prefabricated industried abroad, which will make plans for the dwellings in cooperation with domestic technicians and architects. The form of prefabrication is chosen and the possibilities of using local rawmaterials and labour are studied. Ways of continuous cooperation are studied, keeping in mind especially the establishment of a permanent domestic prefabricated
industry.

(c) - The first dwellings are bought completely prefabricated from abroad and imported dutyfree. At the same time a company is formed with domestic and foreign capital. The foreign shareholder (a prefabricated house factory) may pay for its shares in machines,

drawings, technical help etc. This company takes care of the erection of the imported houses.

(d) - In cooperation a factory is built and a domestic staff is educated to run it independently after a couple of years.

This form of cooperation with the already existing industry of the more developed countries will surely help to avoid many mistakes and expensive experiments. The capital needed is not so important as in many other industries (e.g. pulp and paper), but it is still considerable. The industry has therefore to be established on a sound economic and technical basis.

- In Annex I and II a short calculation is given of the capital needed to establish a prefabrication factory of medium size. These figures can naturally serve only as an example of what costs have to be included in such a calculation, and gives only a general idea of the capital needed.

Other forms of cooperation are also possible (exhange of drawings and information), but in the long run a mutually established and financed industry is likely to prove most successful and guarantees a steady progress.

The establishment of a house factory — Annex I

1. - The total capital needed for setting up the factory depends to a great extent on local conditions. It is here estimated to amount to 0.6-0.8 million dollars. (Annex II)

2. - To begin with, the following machinery and equipment will be needed for the factory:

two	rip saws
one	moulder
three	cut-off saws
one	holzheer
one	tilting table circular saw
one	multiple rip saw
one	hand jointer
one	band saw
one	hollow chisel mortiser
one	air compressor
one	circular saw for cutting insulation material
	dust elevators
two	overhead cranes
	tools
	sharpening machines for moulders
	and circular saws

one lathe
one shaper
one boring machine
black-smith implements
electric welding implements

3. - The energy required by the machinery amounts to 300-500 kWh.
4. - On the above lines the factory can produce some 1000 houses of medium size annually.
5. - 70 workers, 5 foremen and 10 persons for management, sales and planning.
6. - The location of the factory depends naturally on the areas in which it is hoped to sell the houses, and how transport to those areas can be arranged at the lowest cost. It is of course advisable to have the factory near the railway and port.

Capital needed for setting up a house factory — Annex II

(Capacity about 3000 stds/year)

1. - Levelling of terrain, roadbuilding etc. (area 5 acres)	$ 25.000.oo
2. - Factory buildings	
- mill, 14.000 m^3	30.000.oo
- storage of product 35.000 m^3	100.000.oo
- shop, 375 m^3	5.000.oo
- garage, 120 m^3	3.000.oo
- office	15.000.oo
3. - Machinery	
- mill	75.000.oo
- shop	25.000.oo
- spareparts, tools etc.	10.000.oo
4. - Transport facilities	
- one forktruck	20.000.oo
- one lorry	10.000.oo
5. - Drying kiln (4-5 stds/day)	35.000.oo
6. - Power station (steam 5-6 ato)	40.000.oo
7. - Transformer	5.000.oo
8. - Preservation plant	20.000.oo
9. - Office furniture and machines, etc.	15.000.oo
10. - Rawmaterial	
- sawn timber, boards, nails etc.	100.000.oo
	523.000.oo
+ about 15%	77.000.oo
Total	$ 600.000.oo

521 E - Oct. 1962 - 1,600

E/CONF.39/D/63
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ORIGINAL : ENGLISH

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SUMMARY

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Factory Production Of Wooden Buildings And Structures

by

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Summary

The housing problem is very urgent in many less developed areas. However, its solution is very difficult, as investments in housing often have an inflatory effect.

Prefabricated building has several advantages over the conventional method and, therefore, it may, in many cases, lead to a practical and feasible solution of the housing problems.

The author describes briefly different systems of prefabrication. Without going into great detail the pre-cut panel systems and/ are mentioned as the most important. After that dwellings and schools are mentioned as the most important buildings where prefabrication can be practised successfully, also hospitals, army buildings, industrial buildings etc.

Local conditions, such as transport facilities, local rawmaterials and availability of labour affect the form of prefabrication to be used.

In the last paragraph, the author puts the main stress on the importance of the international cooperation in the application of prefabrication in less developed areas. A haphazard start in this new industry certainly will lead to failure. The governments and United Nations specialized agencies have an important task to lead the progress.

In Annex I a short calculation is given of the investment needed for a house factory of medium size.

S - 521 E - Oct.1962 - 1,600

E/CONF.39/D/64
9 Oct.1962
ORIGINAL : FRANCAIS

CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : D.13

France

POSSIBILITES D'EMPLOI DU CONTREPLAQUE DANS LES ELEMENTS STRUCTURAUX ET LES REVETEMENTS DES BATIMENTS

Par Jean COLLARDET,
directeur du Centre technique du Bois
Paris

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

D.13

POSSIBILITES D'EMPLOI DU CONTREPLAQUE DANS LES ELEMENTS STRUCTURAUX ET LES REVETEMENTS DES BATIMENTS

par Jean COLLARDET, directeur du Centre technique du Bois, Paris

I - INTRODUCTION.

Connu depuis près de 50 ans, le contreplaqué est devenu un matériau traditionnel, mais il n'en est pas moins nécessaire d'évoquer les possibilités qu'il offre dans la construction, notamment pour les pays en voie de développement économique, encore pauvres en énergie et en main-d'oeuvre, et dont les ressources naturelles commencent à peine à être exploitées.

Les pays européens de vieille civilisation industrielle ne peuvent guère servir d'exemple. Le contreplaqué, dont les caractéristiques ont beaucoup évolué les 20 dernières années, est loin d'y être utilisé au maximum de ses possibilités.

Seuls les Pays Scandinaves, et surtout dans le Nouveau Monde les Etats-Unis et le Canada, font un très large emploi du bois et du contreplaqué dans la construction.

Dans les pays en voie de développement économique, les entraves dues aux traditionsou au style architectural, qui limitent l'emploi de ces matériaux en Europe Occidentale n'existent pas. La construction traditionnelle, quand elle existe, est généralement inadaptée aux exigences de la vie et de l'économie modernes. Il importe de construire vite et à moindre prix pour pouvoir construire beaucoup. Rapidité, donc préfabrication et édification avec les moyens disponibles en main-d'oeuvre et en matériel et, par suite, construction légère. Quant à l'économie, elle réside dans la possibilité de produire et de fabriquer industriellement, éventuellement sur place, au moins dans un stade ultérieur.

Le bois et le contreplaqué sont, de tous les matériaux de construction, parmi ceux qui exigent le moins d'investissements et de dépenses d'énergie pour être façonnés. La main-d'oeuvre appropriée est facile à grouper et à former. De plus, des ressources en bois d'oeuvre existent souvent - parfois considérables - dans beaucoup de pays neufs à faible peuplement.

Toute construction comporte habituellement dans son gros oeuvre:

- une charpente ou ossature, constituée de fermes traditionnelles ou de poutres horizontales reposant sur des éléments porteurs verticaux qui prennent appui ou s'encastrent sur les fondations;
- des revêtements ou murs extérieurs parfois constitués d'un simple bardage;
- une couverture.

La charpente peut être partiellement ou totalement supprimée si les murs en assument le rôle: planchers "portants", "bacs"de couverture; murs extérieurs et cloisons travaillantes, etc...

Dans tous les cas, la chaîne de fabrication, pour produire économiquement des bâtiments en série, devra utiliser un matériau homogène de caractéristiques constantes, prêt à l'usinage sans façonnage préalable et en grandes dimensions pour réduire les opérations d'assemblage et faciliter le montage; d'où l'intérêt du contreplaqué, matériau résistant et durable sous tous les climats.

S'il ne s'agit pas d'édifier des constructions provisoires mais des bâtiments définitifs dont la durabilité puisse être comparée à celle des constructions en matériaux durs, il sera nécessaire de choisir la qualité de contreplaqué adapté à l'emploi.

II - LE CONTREPLAQUE ADAPTE A LA CONSTRUCTION.-

Si le bois massif entre toujours dans une construction en contreplaqué, ce dernier représente de loin le plus gros volume de matériau utilisé. Il forme à la fois les murs, éventuellement la couverture ou sous-toiture, tout le cloisonnement et l'aménagement intérieur, y compris plafonds et planchers ou sous-planchers. Il est même particulièrement apte à la réalisation d'éléments préfabriqués de charpente légère. Mais il ne s'agit pas de n'importe quel contreplaqué fabriqué sans contrôle suffisant dans n'importe quel atelier mal équipé et avec des matières premières inappropriées. Pour éviter toute déconvenue grave - et même pour prévenir des accidents - il est nécessaire d'exiger certaines spécifications visant la nature de l'essence de bois et de la colle utilisées, la composition des panneaux et le soin apporté à la fabrication.

Il faut utiliser des essences au moins moyennement durables. Il n'est pas question de n'employer que des bois imputrescibles ou résistant naturellement à l'attaque des termites par exemple, d'autant que ces essences ne sont généralement pas déroulables ni aptes au collage. Le respect des principes de bonne mise en œuvre dans la construction et un entretien régulier assureront une parfaite durabilité. Mais il faut cependant écarter absolument certaines essences de bois trop altérables ou trop tendres, quels que soient les avantages qu'elles puissent présenter par ailleurs pour la fabrication du contreplaqué.

La colle utilisée devra être exempte de tout produit organique naturel, rapidement altéré en climat humide. Pour les ouvrages exposés aux intempéries ou à l'eau, on emploiera exclusivement du contreplaqué collé avec une colle de résine synthétique phénol-formol ou résorcine-formol. Cette qualité de collage est d'ailleurs garantie par les Labels et Marques "EXTERIEUR CTB-X" français et "WBP" anglais.

Enfin, la qualité du déroulage et la composition du panneau conditionnent sa stabilité, sa résistance mécanique et même aussi sa durabilité.

On voit que toutes les conditions nécessaires à la fabrication d'un bon contreplaqué de construction peuvent ne pas se trouver réunies sur place, mais le marché international est aujourd'hui assez largement approvisionné pour satisfaire la demande, au moins pendant le premier stade de développement. On ne saurait trop, en tout cas, insister sur la qualité à exiger et sur la réception soigneuse des fournitures.

III - LE CONTREPLAQUE DANS LES ELEMENTS STRUCTURAUX.-

Si le bois massif se prête bien à la construction de charpentes traditionnelles, il est, à lui seul, moins bien adapté à la production en grande série d'éléments structuraux légers préfabriqués. Le contreplaqué permet des réalisations beaucoup plus économiques, soit comme élément de liaison entre les pièces de charpente (gousets ou flasques), soit même comme matériau principal (poutres à âme en contreplaqué en I ou en caissons).

Les exemples de ces réalisations abondent, notamment aux Etats-Unis et au Canada où les applications de contreplaqué dans la construction ont été beaucoup plus développées qu'en Europe. La Grande-Bretagne et la Suède possèdent aussi quelques structures en contreplaqué, mais il faut que le contreplaqué utilisé possède des caractéristiques mécaniques définies, notamment par les contraintes de travail et le module d'élasticité. Ces données supposent une longue expérimentation qui n'a été réalisée, jusqu'à présent, que pour quelques essences de bois: pin d'Orégon, okoumé, hêtre. Dans tous les autres cas, la grande variabilité des caractéristiques naturelles des bois doit inciter à beaucoup de prudence et souvent à l'exécution d'essais statiques effectués sur un échantillonnage bien représentatif de la qualité du lot de contreplaqué. Il est donc nécessaire, pour l'étude préliminaire et l'établissement du plan, de connaître l'essence de bois du contreplaqué et sa composition.

Pour se prémunir contre les défauts de déroulage et de composition des panneaux, il est nécessaire d'imposer une épaisseur limite des plis ou couches de bois qui le constituent et d'exiger toujours - quelle que soit l'épaisseur - au moins 5 plis ou couches à fil croisé. Eventuellement, dans le cas des goussets par exemple, le jointage des plis intérieurs par collage sur chants, pourra être imposé. Enfin, on veillera particulièrement au respect de l'épaisseur nominale dans des limites connues de tolérance.

Rappelons que les assemblages d'éléments en contreplaqué sont facilement réalisés par collage ou clouage avec des pointes fines, nombreuses et bien réparties. Par contre, on évitera d'associer le contreplaqué de façon rigide à des pièces de bois massif trop larges, car le retrait et le gonflement de celles-ci aux variations d'humidité pourrait compromettre à la longue cette liaison.

Voici, pour le contreplaqué d'okoumé - essence parmi les plus utilisées pour la fabrication du contreplaqué en Afrique et en Europe Occidentale - les caractéristiques mécaniques correspondant à des charges permanentes ou de longue durée:

		Contreplaqué okoumé kg/mm2
Contrainte admissible	traction	1
	compression	0,5
	cisaillement ⊥ au plan du panneau	0,5
Module d'élasticité		400 kg/mm2

Ces caractéristiques correspondent aux deux directions principales du panneau (sens du fil des faces et sens perpendiculaire) lorsque le contreplaqué comporte dans son épaisseur autant de bois dans chacune de ces directions. Ils correspondent à une humidité du matériau de 12 %.

D'un point de vue pratique, il n'existe actuellement en France que de rares exemples de structures en contreplaqué. Cependant, certains constructeurs emploient de façon courante des goussets en contreplaqué et, plus rarement, construisent des poutres de petite et de moyenne portée à âme en contreplaqué, surtout des poutres à section en I.

Quant aux planchers porteurs ou éléments de murs rigides en caisson, ils permettent probablement d'importantes économies mais ils supposent une adaptation du projet initial qui est rarement envisagée actuellement par l'architecte.

IV - MURS ET REVETEMENTS EXTERIEURS.-

S'il existe une ossature ou charpente destinée à supporter les charges, les murs et revêtements extérieurs n'ont plus qu'à satisfaire aux conditions d'étanchéité à l'eau et à l'air, éventuellement à l'isolation phonique et thermique. Bien entendu, ils doivent cependant être aussi dotés d'une rigidité propre pour empêcher la flexion locale et d'une dureté suffisante pour éviter la perforation.

Si l'on considère qu'une paroi simple formant bardage peut être réalisée avec un contreplaqué de 10 mm d'épaisseur, la dimension de "maille" pour assurer sa rigidité est de 0,50 m à 1,20 m minimum. Cette solution est adoptée pour les bâtiments agricoles, hangar à matériel, magasins ou granges dont l'isolation thermique n'est pas nécessaire.

Dans les autres cas, on prévoit généralement - au moins sous climat tempéré - un mur extérieur en double paroi. La paroi externe étant en contreplaqué 10 mm, la face interne sera en contreplaqué de 5 à 7 mm d'épaisseur seulement. Pour empêcher une flexion locale appréciable, la "maille" devra être réduite à 0,35 m x 1,20 m au maximum.

La conception classique du "mur" avec une couche de matériau isolant et une barrière de vapeur sur la face chaude de l'isolant, destinée à empêcher la condensation, peut être facilement réalisée. L'humidité qui pourrait néanmoins se condenser dans l'isolant peut en être évacuée par un espace d'air ventilé entre la paroi extérieure et l'isolant.

Il est à remarquer que le bois, comme le contreplaqué, sèchant facilement, ne peuvent guère emmagasiner des quantités importantes d'humidité comme la pierre calcaire, voire la brique ou le béton. D'autre part, l'inertie thermique est presque nulle ce qui, en cas d'atmosphère intérieure conditionnée (chauffée ou réfrigérée) permet de réaliser rapidement le régime d'équilibre. La consommation d'énergie pour ce conditionnement est d'autre part plus faible en raison du faible coefficient de transmission thermique des parois, planchers et plafonds formés de bois et de contreplaqué.

Le problème de l'étanchéité des murs est facile à résoudre, surtout à partir d'éléments préfabriqués. Les joints des dormants des fenêtres et des portes doivent être réalisés en atelier. Pour l'assemblage des panneaux entre eux, des dispositifs d'étanchéité sont prévus à l'avance. Il est important que soient réalisées les conditions suivantes:

1°) - aucun contact avec le sol et possibilité d'écoulement de l'eau de ruissellement sans stagnation. L'étanchéité des chants apparents devra être parfaitement réalisée, notamment par des alèses ou pièces de bois massif et l'application de produits imperméables. Pour les chants horizontaux, l'utilisation de cornières formant rejets d'eau peut être préconisée.

2°) - assemblages verticaux des éléments entre eux par l'intermédiaire de montants ou poteaux en bois massif et non uniquement étanchéité par un joint souple.

3°) - pas de joints horizontaux, sauf recouvrements importants ou dispositifs spéciaux formant rejets d'eau.

Toutes les parties, visibles ou non, où l'eau peut séjourner occasionnellement ou accidentellement, devront être traitées avec un produit de préservation contre la pourriture. Quant à la protection de la surface externe, une bonne solution surtout sous climat tropical ou équatorial, consiste à réaliser une couche d'impression à base de produit anti-cryptogamique, impression qui peut être facilement effectuée en usine. L'entretien n'est plus alors qu'un problème d'esthétique puisque la pourriture ne pourra plus se développer, quel que soit le climat.

Selon les exigences d'aspect, le carbonyle ou des peintures mas$_{o}$uantes ou des vernis extérieurs, notamment des produits glycérophtaliques, donneront de bons résultats.

V - PLANCHERS ET TOITURES.-

L'emploi d'un contreplaqué de 10 ou 15 mm sur solives, comme sous-plancher ou support de moquette, linoléum ou revêtement plastique, peut être conseillé. Les essences utilisées couramment pour la fabrication du contreplaqué ne présentent pas une résistance suffisante à l'usure et au poinçonnement pour que le contreplaqué soit utilisé directement comme surface d'usure. Toutefois, on peut utiliser des panneaux contreplaqués comportant un revêtement protecteur en matière plastique, dur et rigide ou même un revêtement métallique. Le plancher peut aussi être formé d'éléments en caisson préfabriqués s'appuyant directement sur fondation ou muret.

Dans tous les cas, il est indispensable que le sous-plancher soit abondamment ventilé et protégé contre l'accès des parasites animaux - notamment des termites - sous climat tropical. Il est alors indispensable de traiter soigneusement par trempage ou imprégnation profonde tous les éléments de plancher.

La réalisation de toitures en contreplaqué peut se concevoir de différentes manières. La plus simple, et en même temps la plus traditionnelle, consiste à fixer les feuilles de contreplaqué directement sur les chevrons. Pour éviter les détériorations à la pose et les déformations ultérieures, on choisira un contreplaqué de 8 à 9 mm d'épaisseur, la distance entre axes des chevrons ne devant pas dépasser 0,50 m (charge de 100 à 150 kg/m2) ou 0,40 m (charge de 200 à 250 kg/m2).

L'étanchéité aux joints des panneaux posés bord à bord est assurée par une feuille de carton goudronnée ou bitumée ou par enduit de bitume sur kraft ou toile de jute.

On a aussi parfois utilisé le contreplaqué en "ardoises" de petites dimensions, posées à recouvrement comme l'ardoise classique sur voligeage ou sur lattes. C'est évidemment une solution coûteuse et la fixation de ces éléments de recouvrement n'est pas satisfai / avec la quincaillerie habituelle de couverture.
sante

On peut enfin réaliser la couverture par des éléments autoportants, à structure en caisson, qui permettent de supprimer partiellement ou totalement la charpente. Cette solution est facilement adaptable au toit à une pente, voire à une toiture en terrasse sous climat sec. On utilisera généralement à cet effet du contreplaqué comportant un revêtement de métal ou de matière synthétique. L'étanchéité aux joints des éléments entre eux sera assurée par recouvrement avec éventuellement scellement au bitume.

Signalons aussi la fabrication de contreplaqué ondulé, éventuellement imperméabilisé en surface par une feuille d'alliage d'aluminium.

Il faut bien reconnaître que si le contreplaqué utilisé en toiture permet généralement une économie sur le voligeage et le chevronnage et permet de gagner du poids, il constitue, tout compte-fait, un procédé de couverture qui, en Europe, est plus coûteux que l'amiante-ciment ou la tôle ondulée. Il en va sans doute autrement dans les pays qui doivent importer ces matériaux et les transporter sur de grandes distances, l'amiante-ciment étant en outre fragile.

A son actif, on peut retenir sa légèreté, sa résistance, sa souplesse et son faible coefficient de transmission thermique. Mais la technique de pose très particulière n'est pas connue des entrepreneurs, d'où de fréquentes erreurs entraînant l'arrachement ou la détérioration prématurée des panneaux et parfois même le manque d'étanchéité des toitures. Il faut, en outre, faire appel à une quincaillerie spécialement adaptée, comme aux Etats-Unis et au Canada, où les toitures en contreplaqué sont d'un usage assez répandu, malgré la concurrence de nombreux autres matériaux.

Il nous faut enfin faire une place à des techniques toutes nouvelles qui trouvent un écho, surtout en Grande-Bretagne et aux Etats-Unis. Elles s'appliquent essentiellement aux bâtiments de grandes dimensions: halls d'usines, d'entrepôts, d'exposition, de laboratoires. Elles consistent à faire de la toiture même un élément structural en voûte ou en nappe, de forme développable ou non, dont la rigidité assure la résistance de l'ensemble de la construction et son contreventement. L'intérêt technique, et peut être les avantages économiques de ces réalisations, ont été abondamment soulignés dans les rapports et articles de la presse spécialisée. De toute façon, dans sa forme actuelle, cette technique n'est pas applicable à toutes les constructions de moyennes et petites dimensions.

VI - CONCLUSIONS.-

Le cadre restreint de cette communication ne permet pas de concrètiser par des exemples le détail des réalisations de divers types de constructions en contreplaqué. Mais, déjà les avantages du contreplaqué apparaissent clairement, même lorsqu'il est livré directement sur le chantier de construction et doit être débité et assemblé sur place.

Sa mise en oeuvre n'exige que très peu de moyens et de formation professionnelle et la rapidité de construction et d'usage des locaux est incomparablement plus grande que pour toute construction en dur. Mais il est certain que pour satisfaire des besoins importants, la création de chaînes de préfabrication s'impose. On peut alors s'affranchir beaucoup plus des conceptions classiques de la construction. On réalisera alors des gains importants en matériaux et en temps d'exécution et de montage. L'étude d'une "modulation" permettra, avec la même fabrication, de varier les dimensions et l'aspect des bâtiments.

De tous les matériaux présentés en panneaux de grandes dimensions et utilisables dans ces mêmes conditions pour une préfabrication industrielle de série, le contreplaqué est celui qui est, tout à la fois, le moins fragile, le plus résistant par rapport à son poids et le plus durable. Il peut donc supporter des conditions de transport, de mise en oeuvre et de service après construction les plus dures. C'est, en somme, la forme la plus appropriée d'emploi du bois, celle qui en conserve toutes les qualités naturelles en éliminant ses défauts.

Déjà aux Etats-Unis, près de la moitié du bois d'oeuvre est utilisée sous une forme autre que le sciage et, en France, où nous l'avons vu, le contreplaqué est encore très peu utilisé pour le gros oeuvre, près du 1/4 du volume de bois d'oeuvre consommé l'est sous forme de panneaux.

L'intérêt commun commande que soient étudiées et largement diffusées sur le plan international les possibilités d'emploi du contreplaqué dans la construction. Mais, d'ores et déjà, il apparaît que celui-ci est un des matériaux de construction qui permettrait de répondre immédiatement aux besoins des pays en voie de développement.

246 F - Oct.1962 - 1,000

E/CONF.39/D/64
SUMMARY
20 Nov.1962
ENGLISH
ORIGINAL : FRENCH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

SUMMARY

Agenda Item: D.13

France

POSSIBILITIES FOR USING PLYWOOD IN STRUCTURAL UNITS AND ON BUILDING SURFACES

By Jean COLLARDET,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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POSSIBILITIES OF USING PLYWOOD IN STRUCTURAL UNITS AND ON BUILDING SURFACES

By
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Although in the last 50 years or more plywood has become a conventional material, its use in European building carcassing as opposed to American and Canadian practice is unknown.

The barriers against its development in this sphere, tradition and the existence of almost no buildings other than masonry ones, hardly exist in the development countries.

Easy to build, using little plant and labour or energy, plywood is specially useful for the speedy and cheap building of houses, industrial or farm buildings in expanding settlements.

It can be used for all three of the units of the building carcase: the frame, the outside walls and the roof, not to mention the interior.

It is particularly suitable for prefabrication or mass production.

In spite of this, not all plywood can be used for building. It should consist of strong durable timbers, glued so as to stand up to rigorous climate conditions, and must be quality-controlled.

In structural units, plywood can be used for linking pieces together by gussets or side plates etc., or for making the webs of I-section or box girders. Plywood in carpentry should be strong enough to resist known stresses, and should be at least five-ply, the individual thicknesses of the plies being within certain tolerances.

It is possible to imagine self-supporting floors or roofs or external walls made of box-beam structures which allow the frame to be reduced or dispensed with.

In walls and external facing units, plywood can be single- or double-faced, with thermal insulation, vapour barrier, and a ventilated cavity. The outer facing is generally 10 mm plywood, the inside facing 5 to 7 mm.

No plywood covering unit should be in direct contact with the ground. Units exposed to water or damp should be treated with rot-protective.

The watertightness of joints is ensured by solid timber assemblies. The outer surface can be painted or given an "outside" varnishing after treatment against dry rot, and impregnation with insecticide.

The roof can consist of sheets of 7 to 8 mm plywood nailed to ordinary rafters, flush-jointed, and covered with a waterproofing layer. Self-supporting plywood decking with a metal or plastic surface can also be used, and needs neither rafters nor watertight covering. However, in roofing plywood has hitherto been little used because its cost, supplied and fixed, is higher than that of some other economic materials, because of the lack of experience of contractors, and the absence of appropriate metal fittings.

In conclusion, plywood is the most quickly utilized building material, the strongest, and the most sturdy. It satisfies immediately the urgent needs of housing and agricultural or industrial buildings. Plywood buildings can be quickly built, transformed, extended or moved.

The world market is widely supplied with plywood of construction quality. Production lines for prefabricated plywood building units can easily be set up at building sites. Later on, plywood manufacture can make the best possible use of good forest timbers.

S - 246 E - Nov.1962 - 1,600

E/CONF.39/D/65
9 Oct.1962
ORIGINAL : FRANCAIS

CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : D.13

France

POSSIBILITIES D'UTILISATION DANS LES REGIONS PEU DEVELOPPEES DES PANNEAUX DE FIBRES DANS LA CONSTRUCTION

Par Jean-Louis JAUDON,
du Centre technique du Bois,
Paris

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

D.13

POSSIBILITES D'UTILISATION DANS LES REGIONS PEU DEVELOPPEES DES PANNEAUX DE FIBRES DANS LA CONSTRUCTION

Par Jean-Louis JAUDON, du Centre technique du Bois, Paris

Définition du matériau panneau de fibres.-

On entend par "panneau de fibres" ("fibre board" ou "fibre building board" en anglais et "faser platte" ou "holzfaser platte" en allemand) un matériau se présentant en forme de plaque dont l'épaisseur est ordinairement supérieure à 2mm et qui est fabriqué avec des fibres végétales. Sa cohésion résultant du feutrage des fibres, de leurs propriétés adhésives propres, éventuellement de liants ajoutés en très faible proportion.

Ce type de panneau ne doit pas être confondu avec le panneau de particules ("particle board" ou "chip board" en anglais et "spanplatte" ou "holzspanplatte" en allemand) qui est un panneau de petits éléments de bois réagglomérés se présentant également en plaque mais en épaisseur plus forte, (8 mm et plus), et dont la cohésion est obtenue par des liants extérieurs.

Classification des panneaux defibres.-

Celle-ci a fait l'objet d'une résolution adoptée par l'International Standard Organisation (ISO) Organisme de normalisation mondial) lors de sa réunion du mois de mai 1962.

D'après cette résolution, les panneaux de fibres sont classés comme suit, d'après leur masse volumique (ou M.V exprimée en g/cm3) .

Panneaux de fibres	Tendres	mi durs	durs
normaux	m.v. $\leq$ 0,35	0,35 $<$ m.v $\leq$ 0,80	m.v $>$ 0,80
traités	m.v. $\leq$ 0,40	0,40 $<$ m.v $\leq$ 0,85	m.v $>$ 0,85

En fait, on peut retenir qu'il existe deux grands types de panneaux de fibres :

- les panneaux tendres, appelés aussi, souvent, panneaux isolants ou panneaux légers. Ils ont une épaisseur variant généralement de 10 à 25 mm, l'épaisseur la plus courante est 12,5 mm ou 1/2".
- et les panneaux durs comprenant les panneaux mi-durs, durs et extra-durs. Ils ont une épaisseur variant généralement de 2 à 8 mm, l'épaisseur la plus courante est 3,2 mm ou 1/8" .

Pour chacun de ces types il y a les panneaux normaux ou standards, c'est-à-dire n'ayant subi aucun traitement ni aucune transformation après la fabrication proprement dite , et les panneaux traités ou spéciaux qui ont subi des traitements ou transformations qui peuvent être très divers et qui peuvent être exécutés par des entreprises extérieures à la fabrique des panneaux de fibres.

Les panneaux traités ayant tendance à se développer, il est bon d'énumérer les principaux types qui existent sur le marché.

Panneaux de fibres tendres, traités
- perforés, rainurés } généralement découpés en carreaux
- asphaltés
- ignifugés
- revêtus (revêtements divers)

Panneaux de fibres durs, traités
- perforés
- laqués
- plastifiés
- emboutis
- trempés (pour usage extérieur)
- revêtus (revêtements divers)

Aspects de la production et du marché des panneaux de fibres dans le monde.

On rapporte que les japonais utilisent depuis de nombreux siècles, pour la fabrication de maisons légères susceptibles de résister aux tremblements de terre, des papiers spéciaux très épais.

On pourrait voir dans ces matériaux les ancêtres des panneaux de fibres.

Leur industrie, issue de l'industrie papetière, n'a cependant pris naissance que vers 1910 aux Etats-Unis puis, vers 1930, en Scandinavie d'où elle s'est propagée rapidement à toute l'Europe.

La répartition de la production dans le monde et son évolution sont données par le tableau ci-après.

Ce tableau met en évidence la localisation de la production des panneaux de fibres en Europe, U.R.S.S. et Amérique du Nord, ainsi que la persistance d'un fort développement de ces matériaux dans ces régions.

Dans les autres régions du monde qui nous intéressent particulièrement ici, la production est très faible en valeur absolue et presque inexistante si on la rapporte aux populations correspondantes. Elle a cependant un taux d'accroissement très fort.

EVOLUTION DE LA PRODUCTION
DES PANNEAUX DE FIBRES DANS LE MONDE (1)
(en 1.000 tonnes)

REGION	Panneaux tendres			Panneaux durs			Total		
	1953	1957	1960	1953	1957	1960	1953	1957	1960
EUROPE	290	347	372	620	I.041	1.371	910	I.380	I.743
U.R.S.S.	70	41	86	70	53	128	140	94	214
AMERIQUE DU NORD	970	1.012	1.085	480	625	798	1.450	1.647	1.883
AMERIQUE DU SUD				30			30		
AFRIQUE	10			30			40		
ASIE	10			20			30		
PACIFIQUE	30			80			110		
MONDE	1.380		1.543	1.330		2.297	2.710		3.840

(1) selon DEFIBRATOR A B. 1962

Le marché du panneau de fibres est caractérisé par le fait que moins de 20% de la production fait l'objet de transactions internationales.

Le courant essentiel des échanges a lieu entre les pays scandinaves (Suède, Finlande, Norvège) et l'Europe de l'Ouest, principalement la Grande-Bretagne et la Hollande.

Le prix de vente des panneaux de fibres en fait, dans le monde entier, un matériau bon marché dont le cours ne cesse de baisser en valeur relative, en raison du caractère nettement industriel de la production.

Ce sont les pays producteurs et, d'une façon générale, les pays à fort développement industriel qui sont les plus grands consommateurs de panneaux de fibres, ainsi que le montrent les indices de consommation ci-après.

CONSOMMATION DE PANNEAUX DE FIBRES PAR HABITANT ET PAR AN EN 1960 (selon F A O)	SUEDE	24
	NORVEGE	18
	FINLANDE	14
	CANADA	13
	HOLLANDE	10
	ETATS-UNIS	10
	GRANDE-BRETAGNE	6
	ALLEMAGNE OCC.	4
	FRANCE	3
	AFRIQUE DU SUD	2
	U.R.S.S.	1
	INDE	0,04
MOYENNE.....	MONDE.....	1,5

Aperçu sur la fabrication et ses exigences.-

Dans les procédés dits "humides " ("wet process") la matière végétale, généralement bois possédant des fibres longues (donc essentiellement bois résineux) est tout d'abord défibrée sous l'action combinée de l'humidité et de la pression. Les fibres véhiculées par l'eau sont alors conformées en un matelas continu qui est essoré avant:

- d'être séché, lorsqu'il s'agit de fabriquer des panneaux tendres,
- d'être fortement comprimé dans une presse chauffante lorsqu'il s'agit de fabriquer des panneaux durs.

Avec les procédés "humides" on n'ajoute presque aucun liant à la pâte car les liants naturels du bois sont réactivés lors du pressage. La grande quantité d'eau à évacuer sous presse oblige à interposer une grille entre le panneau et le plateau inférieur de la presse, d'où l'aspect "grillagé" d'une des faces du panneau de fibres.

Dans les procédés dits "à sec" ("dry process") qui ont fait leur apparition vers 1955 et se développent rapidement, les fibres sont séchées puis encollées au moyen de liants extérieurs, généralement des résines phénol-formol aux taux de 5% avant d'être conformées à sec en un matelas qui sera fortement comprimé dans une presse chauffante. La chaleur est alors indispensable pour polymériser les résines synthétiques dans des temps compatibles avec un rendement industriel.

Les panneaux fabriqués "à sec" ont donc très généralement deux faces lisses.

L'intérêt des procédés "à sec" réside, de plus, et surtout, dans le fait qu'ils n'exigent pas une matière première ayant des fibres longues (puisque la cohésion vient de liants extérieurs et non du feutrage des fibres) et qu'ils n'exigent pas les très grandes quantités d'eau qui sont indispensables dans les procédés humides (environ 50 m3 d'eau par m3 de panneaux produits)

L'exigence essentielle pour la production de panneaux de fibres réside néanmoins dans la matière première fibreuse. Il s'agit généralement de bois - principalement résineux (tous) mais aussi feuillus (peuplier, bouleau, tremble, aulne, hêtre, tilleul, châtaignier, charme). D'autres végétaux, principalement la bagasse (résidu de la canne à sucre) et la paille des céréales (accessoirement maïs, papyrus, coton) sont également utilisés.

Les investissements nécessaires à la création d'un fabrique de panneaux de fibres étaient estimés, en 1957, pour une production de 25.000 tonnes/an

à environ 25.000 dollars par tonne/jour pour les panneaux durs
et environ 30.000 dollars par tonne/jour pour les panneaux tendres.

Caractéristiques techniques des panneaux de fibres.-

Il convient de distinguer les panneaux de fibres durs des panneaux de fibres tendres.

Les panneaux de fibres durs présentent les caractéristiques moyennes suivantes :

- des épaisseurs de 2 à 8 mm
- une ou deux faces lisses
- des dimensions superficielles de 122 x 244 cm à 200 x 600 cm
- une masse volumique de 0,8 à 1,1
- un module de rupture à la flexion de 200 à 600 k/cm2
- un module d'élasticité de flexion de 20.000 à 40.000 k/cm2
- un module de rupture à la traction parallèlement aux faces de 100 à 300 k/cm2
- une humidité d'équilibre de 5% dans une atmosphère de 20°C de température et 40% d'état hygrométrique
  10% " " " " " 85% " "
- des variations dimensionnelles entre ces humidités d'équilibre extrêmes de : 10% en épaisseur
  0,3% à 0,4% en longueur et en largeur
- un coefficient de conduction thermique de 0,05 C/m2/m/h/°C

Les panneaux de fibres tendres présentent les caractéristiques moyennes suivantes :

- des épaisseurs de 8 à 25 mm ,
- des dimensions superficielles de 122 x 244 à 150 x 300 cm ,
- des faces presque identiques,
- une masse volumique de 0,20 à 0,35,
- un module de rupture en flexion de 10 à 30 k/cm2,
- une humidité d'équilibre et des variations dimensionnelles à peu près identiques aux panneaux durs,
- un coefficient de conduction thermique de 0,03 c/m2/m/h/°C,
- un coefficient d'absorption acoustique de 50 à 60%

Les panneaux de fibres sont donc des matériaux qui se caractérisent par leur présentation en plaques minces possédant des surfaces finies, de très grandes dimensions et de faible poids si on les compare aux matériaux de construction traditionnels.

Leur stabilité dimensionnelle et l'homogénéité de leurs caractéristiques sont très remarquables, comparées à celles du bois dont ils sont généralement issus.

Matériaux élaborés industriellement, leurs caractéristiques peuvent, de plus, être adaptées aux besoins. Il existe, par exemple, des panneaux anti-termites pour les régions où les termites sont à redouter.

Domaine d'utilisation des panneaux de fibres.-

Il est très difficile de passer en revue toutes les possibilités d'utilisation des panneaux de fibres car ces matériaux ayant un caractère très polyvalent ont été utilisés dans un domaine extrêmement étendu. N'appelle-t-on pas le panneau de fibres le matériau aux cent applications différentes ?

Il est donc plus simple de constater que ce ne sont pas des matériaux permettant d'édifier des structures porteuses mais des matériaux aptes à exécuter toutes sortes de revêtements.

A ce titre, ils sont utilisés :

- dans le bâtiment,
  - portes
  - placards
  - cloisons
  - revêtements muraux
  - plafonds
  - sous-parquets ou parquets
  - sous-toîtures
  - doublages ou revêtements isolants divers
  - tous agencements de magasins
  - bardages extérieurs de bâtiments agricoles
  - coffrages.

- dans le meuble : revêtements de parois en caissons
  derrières de buffets, de miroirs,
  fonds de tiroirs,
  portes coulissantes,
  fonds emboutis de meubles de radio et télévision

- dans les agencements : de magasins, bureaux
  de la construction navale

- dans la carrosserie : pour automobiles
  cars et camions
  caravanes,
  avions.

- dans des industries diverses : jouets,
  appareillage électrique
  enseignes et panneaux indicateurs,
  emballages
  meubles frigorifiques.

On conçoit que la diversité toujours plus grande des panneaux de fibres ouvre à ces matériaux de très grandes possibilités d'utilisation dans des domaines jusqu'ici réservés à d'autres matériaux, par exemple :

- au contreplaqué,
- aux métaux légers,
- à la tôle émaillée,
- à l'amiante ciment
- aux panneaux de plâtre,
- aux isolants minéraux.

Techniques d'emploi des panneaux de fibres.-

Celles-ci ne sont pas compliquées et l'on peut penser que c'est la simplicité de sa mise en oeuvre qui a contribué à la vulgarisation rapide du panneau de fibres dans des applications très nombreuses.

Le panneau de fibres étant essentiellement constitué de bois doit être entreposé pendant un à deux jours sur les lieux où il sera employé. D'une façon générale, il y aura intérêt à le mettre en oeuvre à une humidité un peu supérieure à celle à laquelle il se stabilisera en service - éventuellement en l'humidifiant par aspersion d'eau - Ainsi il aura tendance à se tendre sur son support et présentera un aspect plan .

Une autre précaution consistera à ne jamais appliquer les grands panneaux bord à bord mais, au contraire, à réserver un petit espacement en réalisant les joints.

Le découpage des panneaux de fibres standards est aisé. Pour le découpage de certains panneaux spéciaux, ou même pour le découpage en grande série de panneaux standards, il est opportun d'utiliser des outils en aciers spéciaux ou ayant des pastilles de carbure de tungstène rapportées, afin d'obtenir un prix de revient très bas.

La fixation des panneaux peut s'effectuer par tous les modes de fixation traditionnels : clouage, vissage, collage - A noter que le collage est particulièrement approprié à ces matériaux, qu'il y a toujours intérêt à faire travailler par de grandes surfaces étant donné leur relative fragilité locale -

La finition des panneaux de fibres est également très facile, ceci en raison de leur surface très lisse. Ce "fini" que présentent déjà les panneaux permet d'éviter les travaux de préparation indispensable avec le bois ou des matériaux à surface irrégulière ou poreuse.

Exigences de la construction dans les pays peu développés.-

Toutes les études effectuées sur les besoins des pays peu développés sont unanimes pour souligner les besoins primaires et considérables concernant la construction de logements d'habitation
de bâtiments industriels
de bâtiments agricoles
d'écoles
d'hôpitaux
de tous les bâtiments publics nécessaires à une société moderne

Ces besoins sont très certainement dominés par des impératifs d'urgence, de quantité et de bas prix de revient.

Contribution possible des panneaux de fibres.-

Nous avons vu précédemment que les conditions d'approvisionnement des panneaux de fibres étaient favorables dans le monde entier, tant en prix qu'en quantité; qu'il s'agissait d'un matériau bien défini ayant de très nombreuses possibilités d'application dans la construction avec des conditions de mise en oeuvre très simples.

De telles caractéristiques permettent donc d'affirmer que ce matériau est particulièrement susceptible de satisfaire de nombreux besoins de la construction dans les régions peu développées.

Que ce soit dans la construction de logements à usage d'habitation ou dans les autres types de construction énumérés plus haut, il peut être utilisé en sous-toitures, plafonds, revêtements muraux, revêtements de sols, cloisonnements, volumes de rangement et toutes isolations.

Sa légèreté lui permet de se prêter admirablement à la préfabrication.

Sa mise en oeuvre n'exige pas de main-d'oeuvre qualifiée et aucun délai de séchage.

Ses grandes dimensions permettent un travail très rapide, sa finition est très aisée et peut même être supprimée en utilisant des panneaux spéciaux.

Le panneau de fibres qui a fait ses preuves dans les pays industriellement développés du globe est donc, sans aucun doute, un matériau intéressant pour la construction dans les pays en voie de développement.

244 F - Oct.1962 - 1,000

E/CONF.39/D/65
SUMMARY
11 Dec.1962
ENGLISH
ORIGINAL : FRENCH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

SUMMARY

Agenda Item: D.13

France

USES FOR FIBRE BOARD IN CONSTRUCTION IN LESS-DEVELOPED AREAS

By Jean-Louis JAUDON,
Technical Centre for Wood,
Paris

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No. 244 D.13

USES FOR FIBRE BOARD IN CONSTRUCTION IN LESS-DEVELOPED AREAS

By
JEAN-LOUIS JAUDON, TECHNICAL CENTRE FOR WOOD, PARIS.

SUMMARY

Fibre board is defined as a thin material in the form of sheets, made from vegetable fibres, and cohering as a result of the felting of the fibres and their own adhesive properties (sometimes with added binders).

These sheets are classified according to their volume mass into soft sheets and hard sheets, and each type appears either as manufactured (standard) or after processing (treated).

The production of fibre board dates back some fifty years. It is localised essentially in Western Europe and North America and output is used almost entirely (80%) in the production areas.

The cost of fibre board has fallen steadily since its introduction owing to the industrial nature of the manufacturing process.

Fibre board may be made by the "wet" process (water is the vehicle for the fibres and assists the natural bonding of the latter in the hot press) or the "dry" process (air is the vehicle for the fibres which are glued by means of resins, polymerised in the hot press).

The technical characteristics of fibre board, i.e. dimensions, weight, mechanical strength, resistance to humidity and insulating power (thermal and acoustic), are given in the paper.

The sphere of application of fibre board is difficult to define for such a versatile material which finds numerous applications as a facing material in:

building (very wide possibilities) - furniture - fitting out of public buildings - vehicle coachwork - various industries.

Techniques for applying fibre board are characterised by their simplicity; the essential precautions to be taken are preliminary stabilisation and care with joints. The great ease of finishing is emphasised and also the advisability of using fibre-board for large surfaces and not in a localised manner.

The building needs of less-developed countries are mentioned, with special reference to quantity, urgency and price.

The positive contribution of fibre board to meeting such requirements is considered especially interesting owing to the ease of obtaining this cheap material, which can be used in many ways without specialised material or labour.

It can be applied without skilled labour and dries immediately.

Its large dimensions allow of very rapid work, and finishing is very easy and may even be omitted by using special board.

Fibre board has proved its worth in all the industrially developed countries of the world and is undoubtedly a material of interest for constructional purposes in the developing countries.

S - 244 E - Dec.1962 - 1,600

E/CONF.39/D/66
9 Oct. 1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: D.5.1

Finland

CORRUGATED BOARD AND ITS COMPONENTS

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Corrugated board and its components

by Arne Juselius, M. Sc., Head of the

Board Department and Packaging Laboratory of the
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Helsinki (Finland)

1. Introduction

One of the greatest revolutions in the domain of packaging occurred just before the first world war. At that time, board and corrugated board in particular made its mark on the packaging market of the U. S. A. as a really good material for transport purposes in keen competition with wooden forms of packing which had earlier almost exclusively dominated the scene.

In order to achieve this result, the manufacturers of corrugated board had, by means of extensive scientific and statistical investigations, to assure the military and civil authorities, and equally the important railway companies, that the new packaging material provided protection which was at least equal to, and in many instances an even better form of protection than a wood-encased package for an object packed in it. The qualities demanded, and the standards which were then drawn up for corrugated board and packages made of corrugated board, have served as a basis for Rule 41 in the U. S. Uniform Freight Classification which has in its turn functioned as a model in nearly all other countries for the formulation of the corresponding standards and regulations for transport packages.

2. History of corrugated board

Corrugated packaging material was taken into use for the first time in 1871, when the American Albert L. Jones was granted a patent in U. S. A. covering a product which according to the description lodged could be utilized for the packaging of bottles and similar items. This product was made of board, cardboard or other suitable material, and conformed to the quality today known as "corrugated medium". that is to say the corrugated component of corrugated board. This

packaging material patented by Jones had the inconvenience that it was easily stretched and became flat in use, and at the same time lost its elasticity. A patent of 1874 was concerned with an improvement to the new packaging material by sizing a flat paper or board on one or both sides of the "corrugated medium". This packaging material, which corresponds to modern corrugated board, was for a long time used as a wrapper and for the inside lining of wooden containers as well as for cell partitions and protective dividing walls. The production of shipping containers of corrugated board was not initiated until 1894, and from this date it could be stated that corrugated board had really begun its victorious advance as a packaging material.

3. Qualities of corrugated board

The original corrugated paper, "corrugated medium", has with time been developed into the following different types of corrugated board:

a. Single Lined (-Faced) Corrugated Board
with one flat and one corrugated layer

b. Double Lined (-Faced) Corrugated Board
with two flat layers (liners), and one corrugated layer between the liners

c. Double Wall Corrugated Board
with three flat layers and two corrugated layers

d. Triple Wall Corrugated Board
with four flat layers and three corrugated layers.

The flat board layers are usually referred to as liners, such as "testliner" or "kraftliner", and in its turn the material for the corrugated layer is known as "fluting board" or merely "fluting", and at times also "ninepoint" board.

Corrugated board can also be classified into different groups based upon the shape and size of the corrugated waves.

Fortunately, it has proved possible to keep the number of different wave shapes within reasonable limits. Corrugated board is nowadays usually divided into three groups:

	In Europe		In America	
	wave height	wave length	wave heigt	waves per foot
Coarse wave: A-flute	4.8 - 5.5 mm	8.0 - 9.5 mm	3/16"(4.76 mm)	35-37
Fine wave B-flute	3.0 - 3.5 mm	4.5 - 6.2 mm	1/10-1/8" (2.54-3.17 mm)	50-52

	In Europe		In America	
	wave height	wave length	wave height	wave per foot
Middle wave C-flute	3.5-4.5 mm	6.3-7.9 mm	5/32" (3.97 mm)	41-45

"Wave length" refers to the distance between two successive wave peaks.

Recently, there has also appeared an unusual coarse wave type, with a height of about 8 mm and a wave length of over 10 mm. The wave shape varies somewhat, depending upon the manufacturing company, but nevertheless it is possible to distinguish between two main types: one resembling a sine curve, and another with a more pronounced V-shape. Wear of the corrugating rolls, and the milling of worn-out rolls involve that wave shapes are encounted which differ from the main types described above as regards both shape and dimensions.

Generally, the wave is straight; a more snakily sinous wave type is produced only exceptionally.

4. Fluting board

The demands for quality imposed on the board for corrugated medium or fluting were earlier rather modest. Nearly every board quality was suitable for this purpose. Waste paper, knot cellulose, and straw pulp constituted the raw materials for fluting, and the strength properties were regulated through variation of the basis weight. The result was that the basis weight was mostly kept between 180-230 g/sq. m but the strength properties were rather low.

The day-by-day increase in the intensity of competition, the more exacting demands for the strength of transport packages and especially for export containers, coupled with the higher speed of the corrugators have compelled producers to provide new fluting qualities with properties of strength which are in closer conformity with actual requirements.

It is important that fluting board can be corrugated easily and that it also preserves the corrugation. In addition, it should have good sizing properties, be sufficiently rigid, and possess good elasticity in its corrugated state. It is advantageous that the tensile strength, stretch and tear strength are high, whereas the Mullen bursting strength is not so important.

Packaging research has demonstrated that high values for the properties of compression strength and stiffness result in the most satisfactory corrugated-board containers. For this reason, semi-chemical birch pulps have been

the main raw material for fluting board. Semi-chemical fluting board is preferably manufactured in only two basic weights, 112 and 127 g/sq. m. Nevertheless, a quality of 85 g/sq. m is sometimes produced. The values obtained by the Concora Medium Test, CMT, are mostly utilized for the appraisal of different fluting qualities. In general, Finnish semi-chemical fluting board has the following CMT-values:

basis weight, g/sq. m	CMT, lbs
85	ca 40
112	" 60-70
127	" 80-90

Some of the manufacturers of corrugated board consider that a very high value for CMT can cause broken waves, or sizing difficulties. In many cases this, however, only depends on a suitable pretreatment of fluting board, and on an unsufficient knowledge of the sizing properties. Wastepaper, straw, especially wheat straw, bagasse, knot-pulps, etc. are still used extensively as raw materials for fluting board, both alone and in mixtures. Of course, it then becomes necessary to increase the basis weight up to 180 - 230 g/sq. m, and to strike a balance as regards the CMT-values. Large-scale investigations have been engaged in with the aim of improving these properties of fluting board by means of special pulp sizing methods, or by the addition of vegetable slime or synthetic resins, but nevertheless no satisfactory results have been achieved, either with respect to economy or quality.

Semi-chemical pulps for fluting board can be prepared by different methods and from various kinds of wood. However, the best result is obtained by cooking hardwood pulps according to the NSSC method.

5. Linerboard

The liner layer of corrugated board gives many important properties to the corrugated board, and thus the quality of liner board is of considerable significance. In the first place, the liner layer should withstand most of the handling, transport, conditions of climate, etc. to which it is subjected and still possess good sizing, creasing, and printing properties. Thus, a great deal of work has been necessary in order to obtain the best possible qualities of liner for corrugated board. In Europe, the most satisfactory results have been achieved with kraftliner, testliner and kraftpaper. Apart from these qualities, also a large number of other qualities are utilized, depending upon the intended employment of the final corrugated board.

The basis weight of liner board varies within limits, usually between 90-450 g/sq. m, based upon the composition of the pulp and the strength required.

Kraft paper is a tough and strong material which is used extensively, but nowadays it is being more and more pushed aside by the cheaper kraftliner, which is usually produced in large, fast board machines with double headboxes. Testliner is a board of duplex-character with a top layer of bleached or unbleached cellulose, and a body consisting of cheaper pulps such as mechanical pulp, knotpulp, waste paper, etc. It is less expensive than kraftpaper and kraftliner, but it is not so strong. Recently, the addition of up to 50 per cent of short-fibred hardwood pulps to the surface layer of the liner board has provided satisfactory results.

The strength properties of liner board depend on the basic weight, and for this reason there is sought a board quality with a low basic weight and high strength values. Kraftliner occupies a favourable position in this respect. The following values can be reported with regard to the bursting strength of Finnish kraftliner qualities:

basis weight, g/sq. m	Mullen, kg/sq. cm
130	6.3 - 7.0
150	7.0 - 8.0
180	8.0 - 9.5
300	9.5 -10.5

The tensile strength value is high: in the machine direction it is 6000 - 10500 m, and in the cross direction 2.700 - 4.000 m, the respective stretch values being 1.1 - 2.1 % and 2.5 - 5.2 %.

Modern advertising and the supermarkets have observed that the sides of shipping containers are very suitable for publicity purposes, and for this reason nearly all such packages are printed with illustrations and text. This demands a good printing surface, and thus today liner board is to an ever-increasing extent bleached or is provided with a top layer which is completely coloured. However, these methods do not always prove satisfactory, and the coated qualities of linerboard are continuously gaining more footing.

Transport packages should also resist humidity to a major or minor degree, and for this reason linerboard may be waxed, sized with special glues, or with plastic treated. In many cases, the board has to be impregnated against attack by insects or rodents. Packages for tropical transports involve the use of linerboard which is prepared with chemicals, such as phenolates and mercury preparates to resist the formation of mould and fungi.

6. Adhesives

One of the most important components in the manufacture of corrugated board is the adhesive. Generally speaking, the adhesive utilized for fixing the corru-

gated fluting paper to the liner layer is composed of waterglass or starch, and recently certain synthetic resins also.

Waterglass is an adhesive of mineral origin, silicate of sodium, with a composition which varies. If a good sizing effect and a suitable sizing speed are to be obtained, the relation between the amounts of Na_2O and SiO_2 included in the adhesive have to be prescribed; usually there is 8 - 10 per cent of Na_2O and 28 - 30 per cent of SiO_2. The concentration of waterglass varies slightly, but usually it is about 30-40 per cent.

The one-time lower price of waterglass made it the adhesive most generally employed for the preparation of corrugated board, even if it possesses some unfavourable characteristics. It hardens like crystal, and makes the corrugated board rather firm and rigid. Waterglass easily sticks to machine parts of metal, which means that a corrugator must be frequently cleaned; this is a rather troublesome operation. The hardness of waterglass soon blunts the cutting edges, and for the same reason the corrugating rolls are subjected to considerable wear.

Waterglass is fairly sensitive to humidity; this means that the sized seams can be dissolved in a humid state, and the corrugated board will peel. During the subsequent drying period, waterglass will no longer stick the layers together, as happens in a corrugated board sized with starch.

In wet weather, in humid store-places, in tropical countries, and particularly also at low temperatures under humid conditions the sized seams will weaken appreciably during a relatively short period.

The high alkalinity of water glass (pH about 10-11) entails that in certain cases the ability of the liner layer to take size can be affected. Moreover, the colour of the liner board may be changed in such way that there may occur "zebra streaks", especially if the liner layer is made of virgin fibres. If the liner has been produced from waste paper the streak formation is minimal, or does not exist at all. If the corrugated board is printed with alkali-sensitive inks, waterglass can completely destroy the print. The effect of alkalinity is observed most clearly at high relative humidities.

Double corrugated board sized with waterglass needs about 25-30 per cent more adhesive than corrugated board sized with starch. Further to this, the sizing speed for corrugated board sized with waterglass is appreciably lower.

The manufacturers of waterglass have engaged in a great deal of work for the improvement of the properties of waterglass to ensure that they can meet the

keen competition of the manufacturers of starch adhesives.

The use of starch as an adhesive in the preparation of corrugated board originate in the U.S.A., where starch adhesives have almost entirely eliminated waterglass adhesives.

Starch needs a higher sizing temperature, and also en efficient mixing and preparation plant. The storage time for the ready made starch is rather short, often amounting to not more than 2-3 days.

Starch adhesives can easily be removed from the machine rolls and other metal parts of the corrugator. Starch causes no "zebra streaks", and as it is nearly neutral, neither does there occur any discoloration. Starch does not injure packed goods.

Usually, starch adhesive contains about 21-22 per cent starch, together with some additives, such as soda and borax, ingredients which adjust the gelatination temperature and the viscosity.

Starch adhesives with good wet strength properties can be obtained by adding certain chemicals and resins such as ureformaldehyde, melaminformaldehyde, aluminum sulphate, and recently resorcinol resins also. At the moment, the starch manufacturers are working energetically to improve their products in this respect. The starch quality which gives the best results is prepared from corn.

Corrugated board sized with starch does not possess such satisfactory stiffness as corrugated board sized with waterglass, and some consumers consider this to be a great disadvantage in the production of corrugated containers. Corrugated board sized with starch is a suitable packaging material for tropical conditions and for other extreme conditions of climate as a consequence of its good wet strength and low hygroscopicity.

The continuously increasing demands imposed on corrugated board and the fastmoving corrugators, the speed of which is constantly rising, have brought in their train new adhesives based upon synthetic resins. Good results have been obtained with polyvinyl-acetate. Large-scale experiments with many different qualities of synthetic resins have been carried out, and this testing work is still in progress, especially in the U.S.A. One of the most important aims is that of producing, if possible, a cold-jointing adhesive, which would provide an opportunity to eliminate the long drying section in the corrugated board machine.

7. Conclusion

Increasing mechanization and automation in the handling of goods, the greatly intensified exchange of commodities and foodstuffs, expanding international trade, the development of speedy transportation vehicles, along with many other factors, have led to the immense progress and distribution of packages made of corrugated board. As a country develops, the greater become its demands for efficient, light, and inexpensive means of packaging. Corrugated board has become an ideal packing material, and shows every possibility of being converted into still better qualities, and of becoming even more popular and widely used.

Unfortunately, it is a very difficult matter to obtain statistics on the actual consumption of corrugated board in different countries, and to find a comparable index which could indicate the consumption per capita in these countries. The vital organisation, Fédération Européenne des Fabricants de Carton Ondulé, F.E.F.C.O. has provided the following information on the consumption per annum and per capita in 1960:

USA	43.8 kg	Switzerland	8.4 kg
Sweden	14.4 "	Italy	6.8 "
Holland	14.7 "	Belgium	5.9 "
Germany	10.2 "	Norway	5.9 "
England	10.1 "	Austria	2.6 "
France	10.1 "	Spain	0.7 "

Harry J. Bettendorf has carried out a large-scale investigation of the production of corrugated board; he arrived at the following results reported in sq. ft. per capita in 1960:

Egypt	6.4	Italy	117.4
Greece	7.1	Denmark	127.5
Portugal	11.0	Switzerland	144.2
Spain	13.2	France	144.5
Austria	45.9	United Kingdom	175.5
Finland	104.3	Western Germany	208.2
Belgium	104.9	Sweden	283.9
Norway	113.9	USA	593.8
Israel	114.8		

This list is by no means complete; the Eastern States and the development countries are not included.

The development countries, for which there has been planned an efficient utilization of natural and industrial products, will soon in many respects need suitable packaging material for the home market and for export. In these countries, corrugated board will also be the most important packaging material. The rise in demand will certainly result in the importation of packaging materials or the initiation of home production. Unfortunately, the transportation of corrugated

board or of containers of corrugated board cannot be recommended except in special cases, particularly as regards remote countries, as in view of the space required for corrugated board its transportation will be un economic; for corrugated board, the space required is about 3-6 times as much as for linerboard and fluting.

The development countries, usually situated far from the countries actually producing corrugated board in Europe and in America, will increase their needs and demands for an efficient packaging material for their consumption products and export goods. The construction of corrugated board mills, complete with container plants, in consumption or export centres, or nearby, soon enters one's mind, and this is also rather easy to realise. Modern corrugating machines are efficient and versatile, with a speed of over 200 m/min. The staff need not be large in number and the plants are easy to set up and to maintain.

The raw material, fluting, liner and adhesive can, at least initially, be obtained from those countries which over-produce. Later on, opportunities will arise for the manufacture of fluting board and liner-board from the raw materials of each country, from bagasse, straw, hard- and softwoods, but this will constitute a larger scale economic project and will require in addition well-trained foremen and skilled workers.

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E/CONF.39/D/66
SUMMARY
9 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

SUMMARY

Agenda Item: D.5.1

Finland

CORRUGATED BOARD AND ITS COMPONENTS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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Corrugated board and its components

by Arne Juselius, M. Sc., Head of the

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Summary

The consumption of paper and board, reported in weight units per capita and per annum, gives some idea of the development attained by the country concerned. Paper and board making involves the production of a large number of different qualities, in many cases intended for special purposes. In the packaging field particularly, the development of suitable materials has been vigorous during recent years.

Among packaging materials, corrugated board has found increasing use year by year, and its quality has steadily improved. It is a light and efficient packaging material, although its size means that it is hardly suitable for export. For preference, it should be manufactured in the country of consumption. The corrugating machine is relatively simple construction, and there are very few difficulties in operation and maintenance.

The surface layer of the liner board can be bleached or unbleached: normally it consists of high-quality sulphite or sulphate pulps. The body is made up from cheaper waste pulps, waste paper, semi-chemical pulps, and so on. Recently, the addition of up to 50 per cent of short-fibred hardwood pulps to the surface layer of the liner board has provided satisfactory results. Fluting board, which was at one time made of different types of cheap fibre material, such as waste paper, straw, waste pulp, bagasse, etc., is nowadays generally produced from semi-chemical hardwood pulps, which afford to the corrugated board a good degree of stiffness and high crush strength.

The glue utilised constitutes an extremely important component of corrugated board. It must stick quickly, and preferably possess wet strength. Further-

more, it must not introduce discoloration. Especially in a tropical climate, the demands made on corrugated board are high, and often entail treatment of it by paraffin or chemicals.

With the aid of packaging research, great strides have been made in the testing of corrugated board, and satisfactory results have been achieved.

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